CHARGE

Smart Charging Connection network case studies: Final Report

The Charge Project
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Tables

Figures

2. Introduction

The Charge Project is designing and demonstrating innovative Smart Charging Connection (SCC) solutions for electric vehicle (EV) charging. These solutions will provide EV chargepoint developers with a greater range of connection options and accelerate the roll-out of public EV charging infrastructure.

2.1. Project Background

Led by SP Energy Networks (SPEN), in collaboration with EA Technology, PTV Group and Smarter Grid Solutions, the Charge Project is accelerating the process of planning and connecting EV charging infrastructure at the lowest-possible cost to GB electricity customers. This is achieved by maximising the use of existing assets and deploying innovative approaches to connection and management of EV uptake across SPEN's Manweb licence area, which covers Merseyside, Cheshire, North Shropshire, and North & Mid Wales.

The Charge Project combines learning from other EV charging projects with expertise from the world of transport planning. This insight will be coupled with a targeted selection of innovative EV chargepoint connection trials for a range of practical situations.

The Charge Project merges the disciplines of transport planning and electricity network planning to create an overview of where EV chargepoints will be required and how the network will be impacted by chargepoint connections. This approach facilitates better planning of electricity networks and provides vital information for all sectors involved in helping the UK transition to low carbon transport.

The project uses driver behaviour and journey statistics to form a view of the likely demand draw from multiple EV chargepoint installations in various uses (for example, car parks, forecourts, retail/leisure destinations), which will help the distribution network operator (DNO) assign more appropriate design values during the connection process.

The Charge Project includes three methods:

- **Method 1:** Strategic transport and network planning
- **Method 2:** Tactical solutions to support EV connections
- **Method 3:** Development of the 'ConnectMore' software tool

Smarter Grid Solutions (SGS) is responsible for Method 2, which designs and demonstrates SCC solutions that enhance the flexibility of EV charging and support improved hosting of charging infrastructure without expensive reinforcement.

Previous phases of the Charge Project have defined a 'smart solutions toolbox' of flexible EV charging solutions, which will be demonstrated through trials in subsequent phases of the project.

The Charge Project has consulted with stakeholders across the distribution networks and the EV domain, using learning from this process to refine SCC offerings. This has established two forms of SCC:

- **Customer-led SCCs:** the customer is responsible for managing EV chargepoint consumption against pre-agreed, fixed import limitations
- **DNO-led SCCs:** the customer must manage EV chargepoint consumption against a varying import threshold that reflects prevailing network conditions

For each of the above SCCs, multiple forms of solutions can be deployed, each of which have varying degrees of complexity and capacity release.

2.2. Document Objectives and Structure

This document is aimed at a range of stakeholders, including EV chargepoint operators and developers, DNOs and Ofgem. The objective is to report on the learning derived through the Successful Delivery Reward Criteria (SDRC) 5 project stage.

SDRC 5 has studied and demonstrated the deployment of SCCs on network case studies. Analysis of historical EV chargepoint utilisation datasets has improved understanding of chargepoint utilisation and supported the derivation of representative profiles. Through the delivery of desktop assessments, the anticipated level of SCC intervention is approximated across a range of study scenarios and network cases.

SDRC 5 has designed and implemented Virtual Trials, configuring the SCC control infrastructure in a laboratory simulation environment and modelling the emergence of network constraints using representative SPEN network datasets.

This document presents learning from SDRC 5 through the following structure:

- Section 3 presents the findings and key learning from detailed study of historical datasets from public EV chargepoint infrastructure.
- Section 4 illustrates the methodology and key learning from desktop assessment of charging infrastructure.
- Section 5 presents the design and test cases demonstrated through the Virtual Trials. It presents learning from the design, configuration, and commissioning of the SCC solution in the Virtual Trial laboratory environment.

3. Chargepoint Data Analysis

The Charge Project has accessed historical datasets of EV chargepoint utilisation, sourced from several chargepoint operators (CPOs) and representing sites across South Scotland and Northern England. The study of these datasets has improved understanding of EV chargepoint behaviours and informed the modelling of EV chargepoint operation in follow-on virtual trials and desktop assessments. Characteristics of EV chargepoint utilisation, such as duration, energy consumption during charging events, and total utilisation of EV chargepoints, are derived across the different types of chargepoint.

Understanding the typical utilisation levels of EV chargepoints is crucial to the subsequent evaluation of SCCs, the frequency and severity of constraint events, and ultimately, the impact of constraint events on customers using an EV chargepoint site.

This section details summary findings from the initial statistical review of the CPO datasets of chargepoint utilisation.

3.1. Source Datasets

EV chargepoint datasets were obtained from five sources; these detailed approximately 54,000 charging events across 162 chargepoint units. A summary of the data sources is provided in Table 1. A description of the specific information provided for each source is detailed in the following sections.

Source	Sites/ Chargepoints	EV Chargepoint Type	Dataset Start	Number of Charging Events
PACE – Lanarkshire, Scotland	16 sites; 54 chargepoints	Destination	August 2020 to September 2021	49,977
Q-Park – Yorkshire, Lancashire, and Merseyside	22 sites; 28 chargepoints	Destination	January 2020 to March 2021	1,792
Liverpool Lamp-Post Chargers	63 sites & chargepoints	Residential	January 2020 to December 2020 April 2021 to June 2021	1,417
Cheshire West & Chester Car Parks	7 sites; 15 chargepoints	Destination	September 2021 to November 2021	809
Warrington Times Square Car Park	1 site; 2 chargepoints	Destination	June 2020 to May 2021	507

Table 1: Summary of Available Datasets

The EV chargepoints within the datasets mainly consist of Destination charging sites, with a smaller proportion from On-Street Residential charging sites. A universal dataset of EV charging events was derived from the diverse datasets, and presented the following information in a consistent format:

- **Source:** the original source of the event dataset
- **Site Unit:** a unique identifier for the chargepoint used in the charging event
- **Charging Type:** whether the chargepoint type is one of Destination or On-Street Residential
- **Charge Event Start Date and Time:** the date/time the EV connected to the chargepoint
- **Charge Event End Date and Time:** the date/time the EV disconnected from the chargepoint
- **Charge Duration:** the duration the EV was connected to the chargepoint during the charge event
- **Energy Consumption (kWh):** total energy consumed by the EV within the charging event window
- **Average Charge Rate:** the average rate of charge across the full charging event

3.2. Summary Findings

Several key behaviours have been derived from statistical evaluation of the metrics available in the universal datasets of EV charging events. These are summarised as the following four factors:

- **Time of Events:** understanding when charging events occur, namely, at what time of day or year there is greatest demand for EV chargepoint usage
- **Duration:** understanding the typical duration of EV connection to the chargepoint throughout a charging event
- **Energy Consumption:** understanding how much energy is consumed across the range of typical charging events in the datasets
- **Per-site Utilisation:** understanding the typical availability of EV chargepoints, such as the probability that the chargepoint is available for an EV connection, or the number of chargepoint events per day

Observations from the study findings include the following (which are detailed further in later sections):

3.2.1 Time of Events

A high proportion of all charging events are initiated during daytime hours, particularly between 08:00 and 17.00. As most event data is related to Destination charging, there is strong correlation between chargepoint utilisation in these hours and operational hours of destinations such as shopping centres, public transport park-and-ride sites and leisure facilities.

In the case of On-Street Residential charging, charging events tail into the evening, which is distinct from the abrupt decline observed in Destination charging after 17.00. This likely represents utilisation of on-street residential chargepoints in the evening when commuting users return home from work.

3.2.2 Duration

Study of EV charging event duration highlights a notable distinction in event duration between the Destination and On-Street Residential cases: Destination cases show the majority (over 80%) of charging events lasting under two hours, whereas the On-Street Residential cases observe that over 45% of charging events last more than six hours. This observation may reflect behaviour in which once a user has connected to an On-Street Residential chargepoint, they may not disconnect until the next car journey. This can be contrasted with behaviour at a Destination site, where the car will be disconnected when the user must continue their journey.

Most available datasets only highlight the window of EV connection to a chargepoint, rather than the period when the EV is actively drawing power from the chargepoint. In practice, during longer events the EV may reach full charge during the event, which results in part of the charge window involving no electrical energy consumption at the chargepoint. This is a significant limitation when evaluating both EV user behaviour and the grid import impacts of charging events across a time-series connection window.

A key recommendation is for CPO operational logging to be configured to measure the distinction between the true 'charging window' and 'connection window' of a connected EV. Logging this information would facilitate more accurate study of the electrical demand impacts of EV charging events.

3.2.3 Energy Consumption

Across all chargepoint types, approximately 50% of charging events consume less than 20 kWh. This may relate to the nature of Destination charging or reflect that in many cases of public chargepoint utilisation, EV users are merely 'topping up' their charge.

In the case of On-Street Residential, a marginally higher percentage of charge events consume over 60 kWh (when compared to Destination charging). This may be related to the larger proportion of long-duration charging events in the case of On-Street Residential charging (as explained in Section 3.4).

3.2.4 Per-Site Utilisation

General trends suggest that chargepoint utilisation can follow two behaviours:

- High Frequency Events/Low Duration: the chargepoint experiences multiple low-duration (sub-hour) events in one day, most often observed at Destination charging sites.
- Low Frequency Events/High Duration: the chargepoint may only experience a single charge event in one day, but it is likely to be a minimum of two hours' duration. This is most often observed at On-Street Residential charging sites.
- On average, there are higher levels of utilisation across the PACE datasets when compared to most other data sources. This may reflect the fact that PACE chargepoints are free for public use, whereas other customers must pay for use of other chargepoints, which could cause users to defer charging to cheaper, at-home periods.

Across the periods covered by the operational datasets, a large proportion of data was recorded during the COVID-19 lockdown, when utilisation of public chargepoints was lower than typically expected. For this reason, we propose a return to this analysis, deriving updated metrics using more detailed datasets from 2021 and 2022 to validate (or otherwise) the findings from this study.

3.3. Data Analysis Outputs: Time of EV Connection Events

The timing of EV charging events is concerned with the initial moment of connection of the EV to the chargepoint. It illustrates the user demand for chargepoint availability at certain times of the day, and can also be used as a proxy to identify the period of peak/highest demand at the beginning of a charging event.

The start times of EV charging events are aggregated to half-hour windows, with the number of events in each window used to derive the following:

- Figure 1 illustrates the distribution of charge event start times across the day, obtained from all data sources.
- Figure 2 illustrates the probability of charging event start times for each source of data.
- Figure 3 illustrates the breakdown in probability of charging event start times across Destination and On-Street Residential sites.

Figure 1 details the number of charging events that start in each half-hour window, broken down across the dataset sources.

Observations from the study of EV charging start times are:

- There is a significant trend for charging events to start during daytime hours, particularly between 08:00 and 17:00, as highlighted in Figure 1. As most event data is related to Destination charging, there is strong correlation between chargepoint utilisation during these hours and the operational hours of destinations such as shopping centres, public transport park-and-ride sites, and leisure facilities.

- In the case of On-Street Residential charging, the charging events tail significantly into the evening, as opposed to the more abrupt decline in Destination charging after 17:00. (See Figure 3.) This likely represents utilisation of On-Street Residential chargepoints in the evening, when commuting users return home from work.
- The specific morning peak observed in the Warrington Town Centre dataset (Figure 2) reflects expected behaviour at city-centre car park sites, where commuting users are likely to initiate charging events just prior to the working day.
- As shown in Figure 2, the sources with smaller populations of charging events present higher levels of variation across charging start times. This factor is likely to affect the comparison between the On-Street Residential datasets, which reflect greater variation, and the smoother pattern observed in the Destination datasets (see Figure 3), in that there is a significantly higher population of Destination events.

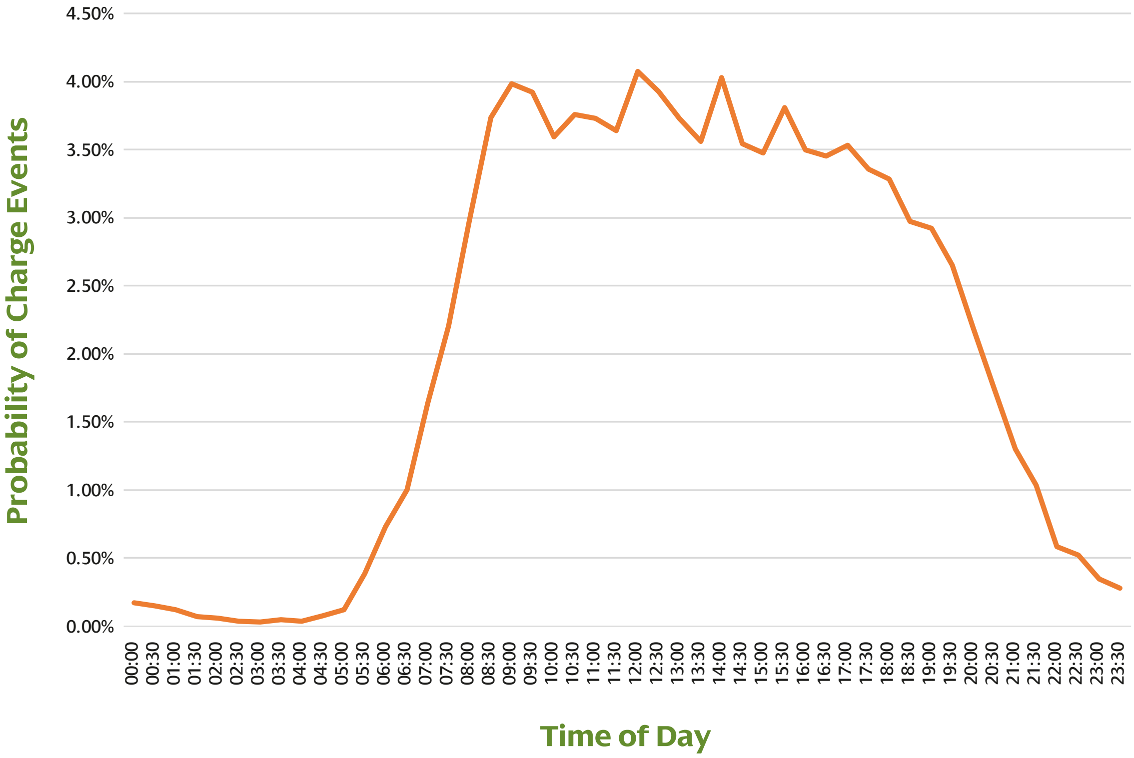

Figure 1: Charging Event Start Time: Number of Charging Events (All Data)

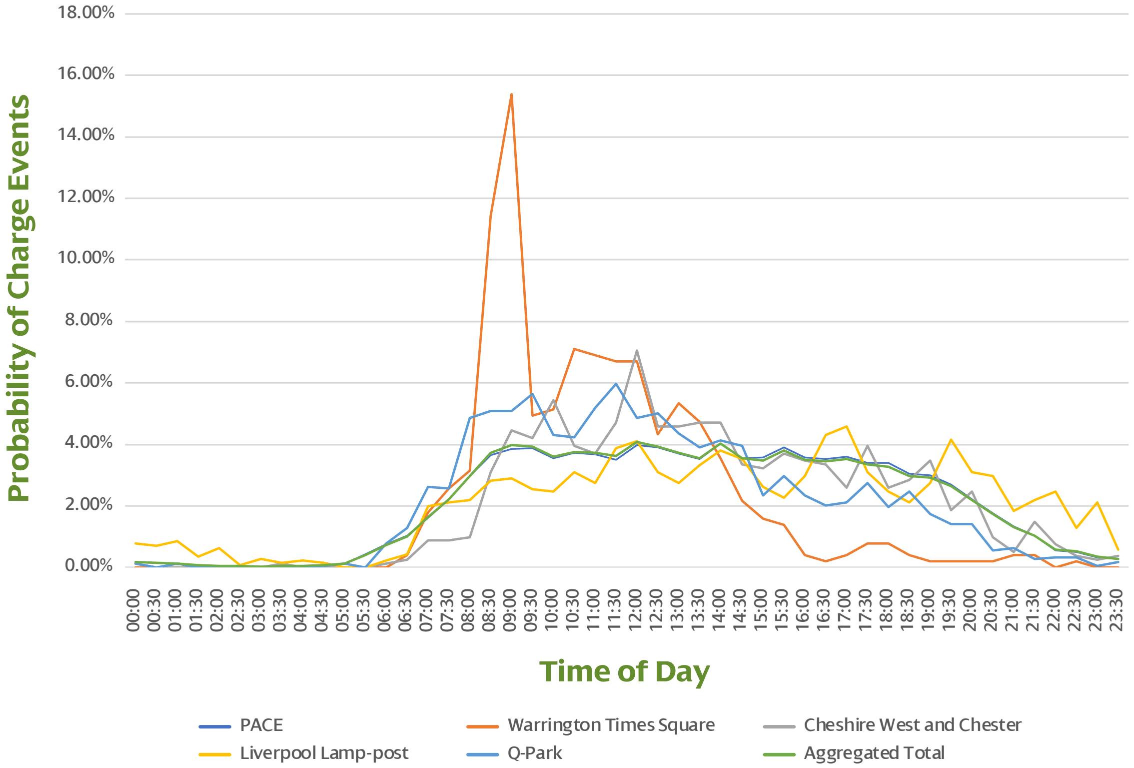

Figure 2: Charging Event Start Time: Probability of Charging Events per Source

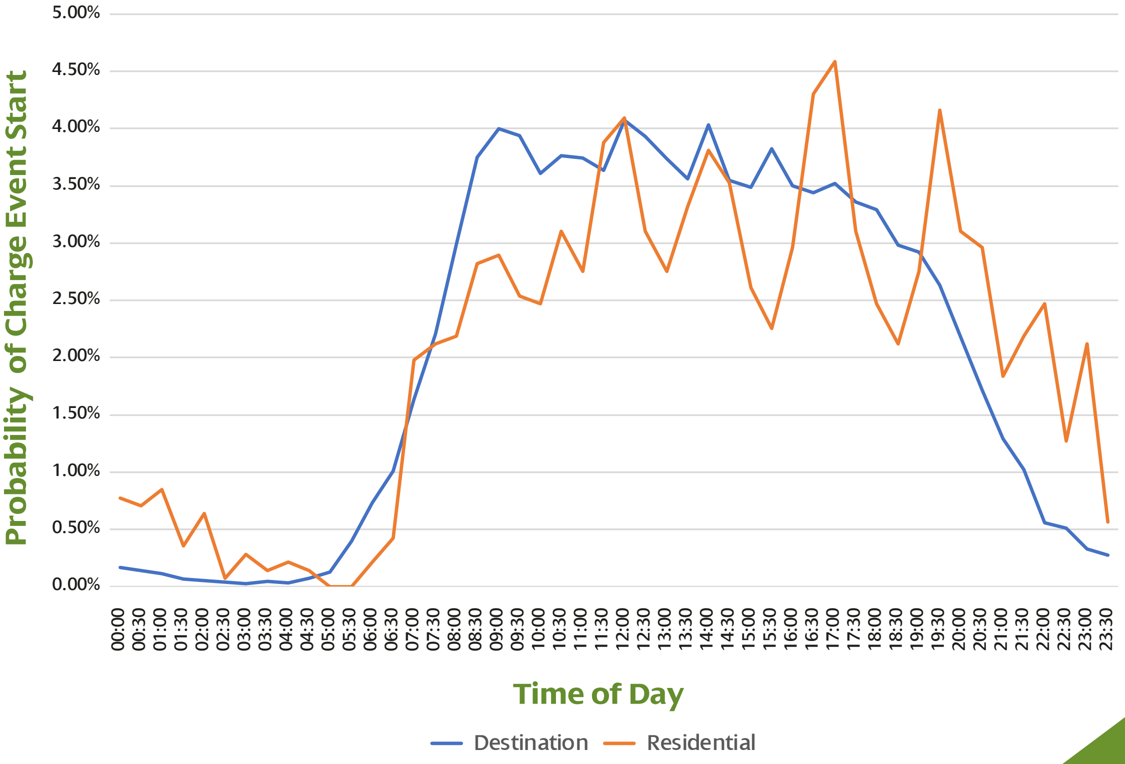

Figure 3: Charging Event Start Time: Probability of Charging Events per Chargepoint Type

3.4. Data Analysis Outputs: Charging Event Duration

Like the start times of EV charging events, the duration of events reflects an important factor in user behaviour. Study of event duration assists in understanding the utilisation levels of different chargepoint types and associations between utilisation and number of users.

> *The key observation from the study of EV charging event duration is that there is a notable distinction in event duration between the Destination and On-Street Residential cases.*

Whilst the charging event duration metric describes the period during which an EV is plugged into a chargepoint, in practice the EV may reach full charge during a longer event, resulting in part of the charge window involving no electrical energy consumption at the chargepoint at all. Improvement in collection of CPO operational datasets to differentiate between the true 'charging window' and 'connection window' would allow more accurate study of the electrical demand impacts of EV charging events.

The duration of individual EV charging events is grouped into event windows, and the following is presented:

- Figure 4 illustrates the probability of charging events lasting for different duration levels, broken by each of the data sources.
- Figure 5 illustrates the probability distribution of charging event duration levels across Destination and On-Street Residential sites.

The key observation from the study of EV charging event duration is that there is a notable distinction in event duration between the Destination and On-Street Residential cases: Destination cases show the majority (over 80%) of charging events lasting under two hours, whereas On-Street Residential cases observe that over 45% of charging events last longer than six hours. This observation may reflect behaviour in which once a user has connected to an On-Street Residential chargepoint, they may not disconnect until the next car journey. Conversely, at a Destination site, the car is likely to be disconnected when the user must continue their journey.

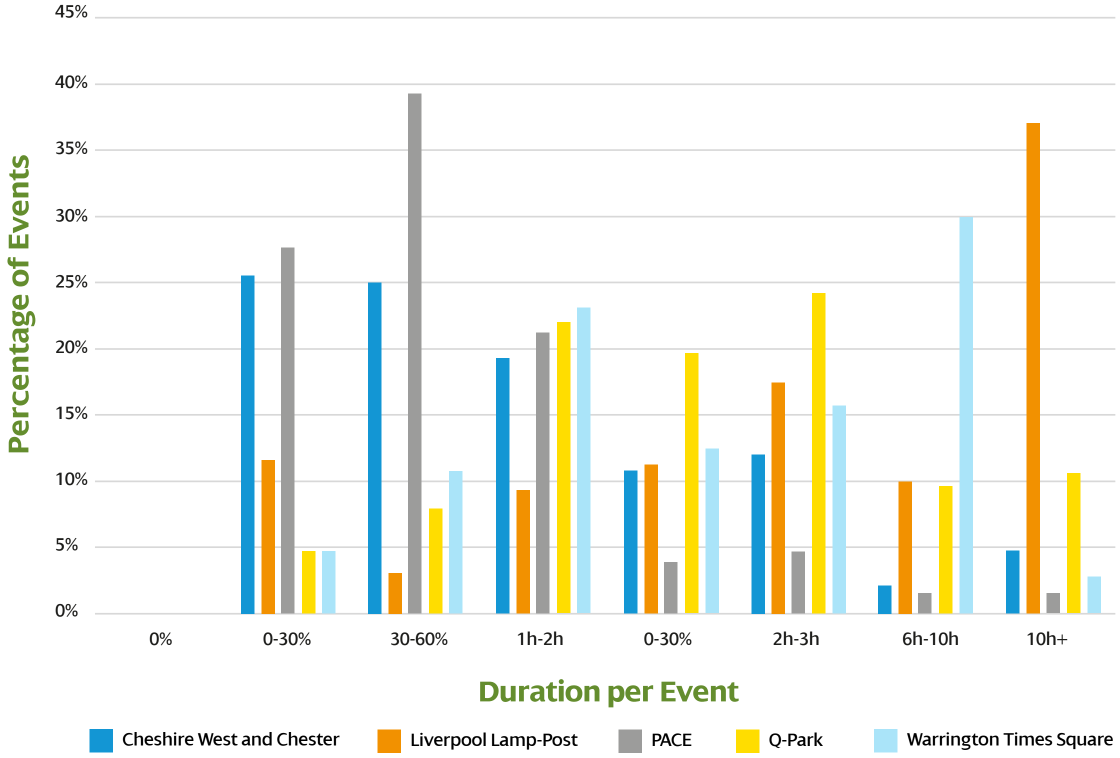

Figure 4: Charging Event Duration: Probability per Data Source

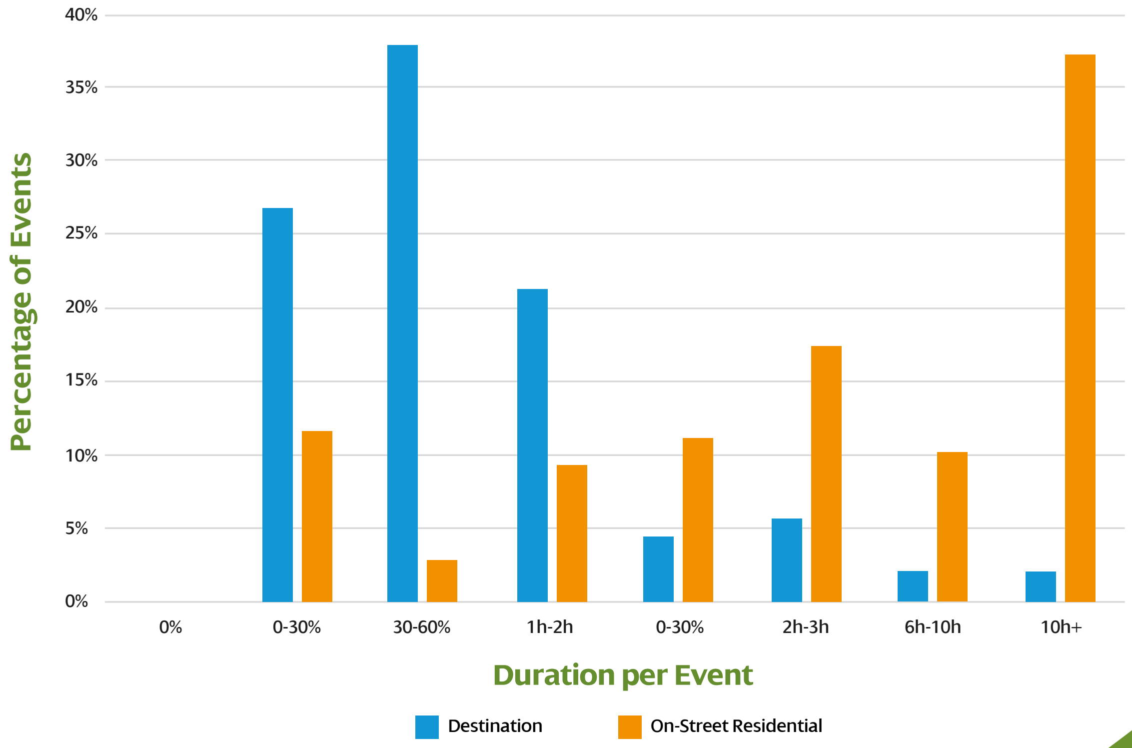

Figure 5: Charging Event Duration: Probability per Chargepoint Type

3.5. Data Analysis Outputs: Energy Consumption

The energy consumed at chargepoints assists us in understanding the links between customer behaviour, EV chargepoint utilisation levels and the types of EV chargepoint.

The energy consumption within individual EV charging events is aggregated into blocks of kWh consumption across the event. It is important to note that energy consumption at a chargepoint will be influenced by not only the chargepoint rating, but also the type of EV (which will dictate both rate of charge and battery capacity), the starting state of charge of the EV, and the duration of the charging event. Figure 6 illustrates the probability distribution of charge event consumption derived from all data sources.

Observations from the study of consumption during EV charging events are:

- Across all chargepoint types, approximately 50% of charging events consume less than 20 kWh. This may relate to the short-term nature of user parking at Destination spaces or reflect that in many cases of public chargepoint utilisation, EV users are merely ‘topping up’ charge rather than requiring an essential recharge of the EV battery.
- In the case of On-Street Residential, there is a marginally higher percentage of charge events that consume over 60 kWh (when compared to Destination charging). This may be related to the larger proportion of long-duration charging events in the case of On-Street Residential charging, as noted in Section 3.4.

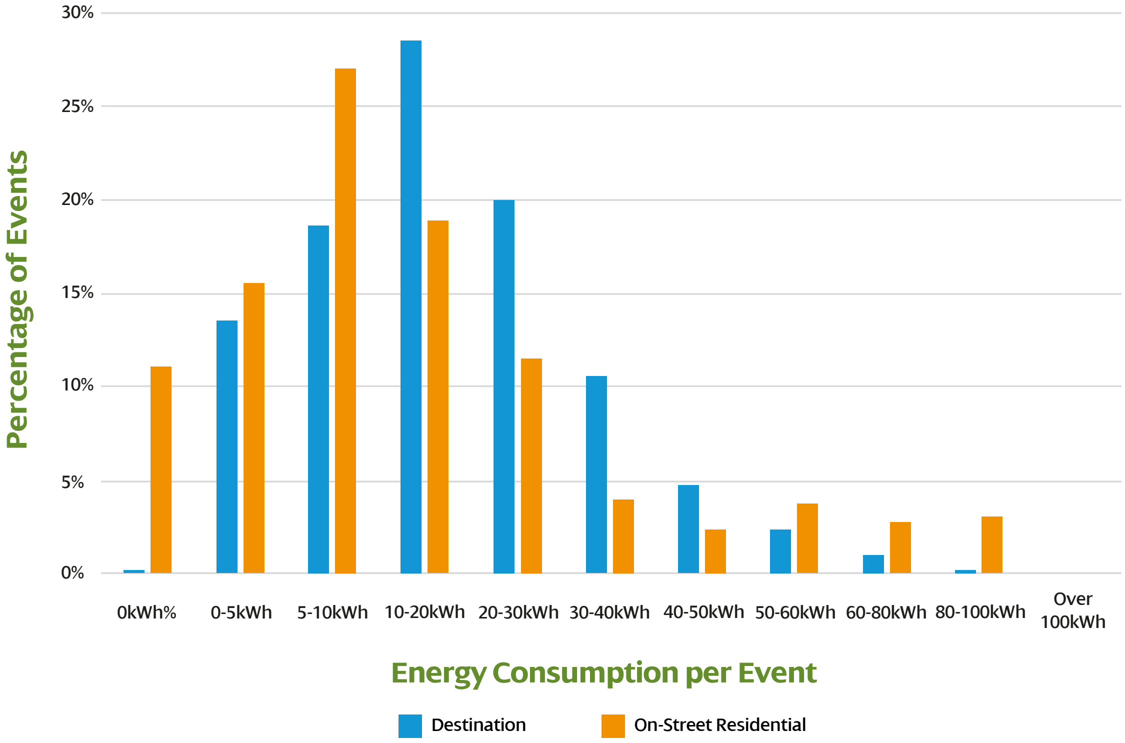

Figure 6: Charging Event Consumption: Probability per Chargepoint Type

3.6. Data Analysis Outputs: Per-Chargepoint Utilisation

Utilisation metrics are derived on a per-chargepoint basis, in which the following metrics are determined for each chargepoint:

- The **average number of charge events per day:** calculated as the total number of charging events at the chargepoint, divided by the total number of chargepoint operational days
- The **average duration of charging events:** calculated as the total duration of charging events at the chargepoint, divided by the total duration of chargepoint operation

In the calculation of both metrics, the operational window for each chargepoint is defined as the period between the start of its earliest charging event and the completion of its latest charging event. It is possible that less-utilised chargepoints may have been operational for longer periods in the study window, but without clear information on per-chargepoint dates of data collection, the applied approach provides the most representative and consistent method for deriving chargepoint operational windows. Similarly, information about chargepoint downtime was not available to incorporate into the utilisation calculations.

Figure 7 presents a plot of the above metrics for each chargepoint, in which the chargepoints are colour-coded to reflect source datasets. Table 2 details the average utilisation of chargepoints across each source dataset. Observations from the per-chargepoint metrics are:

- It is noted that, with the exception of a small number of outliers, the PACE Destination charging dataset is the only source dataset that returns more than one average number of charging events per day. Where a chargepoint sees more than one event per day, the average event duration is most often below one hour.
- Conversely, the Liverpool Lamp-post On-Street Residential chargepoints return a higher average duration of charging events, although almost all chargepoints see less than one charge event per day. The long-duration charge events reduce the overall availability.
- General trends suggest that chargepoint utilisation can follow two behaviours:
    - High Frequency Events/Low Duration: when the chargepoint experiences multiple low-duration (sub-hour) events in a day
    - Low Frequency/High Duration: when the chargepoint may only experience a single charge event during the day, but it is likely to be a minimum of two hours' duration
- On average, there are higher levels of utilisation across the PACE datasets when compared to most other data sources. This may reflect the fact that PACE chargepoints are free for public use, whereas other chargepoints charge customers, potentially causing users to defer charging to the cheaper at-home period. The site-selection process for PACE chargepoints was undertaken in partnership with Transport for Scotland, in order to ensure that charging hubs were in areas where communities were adopting EVs.

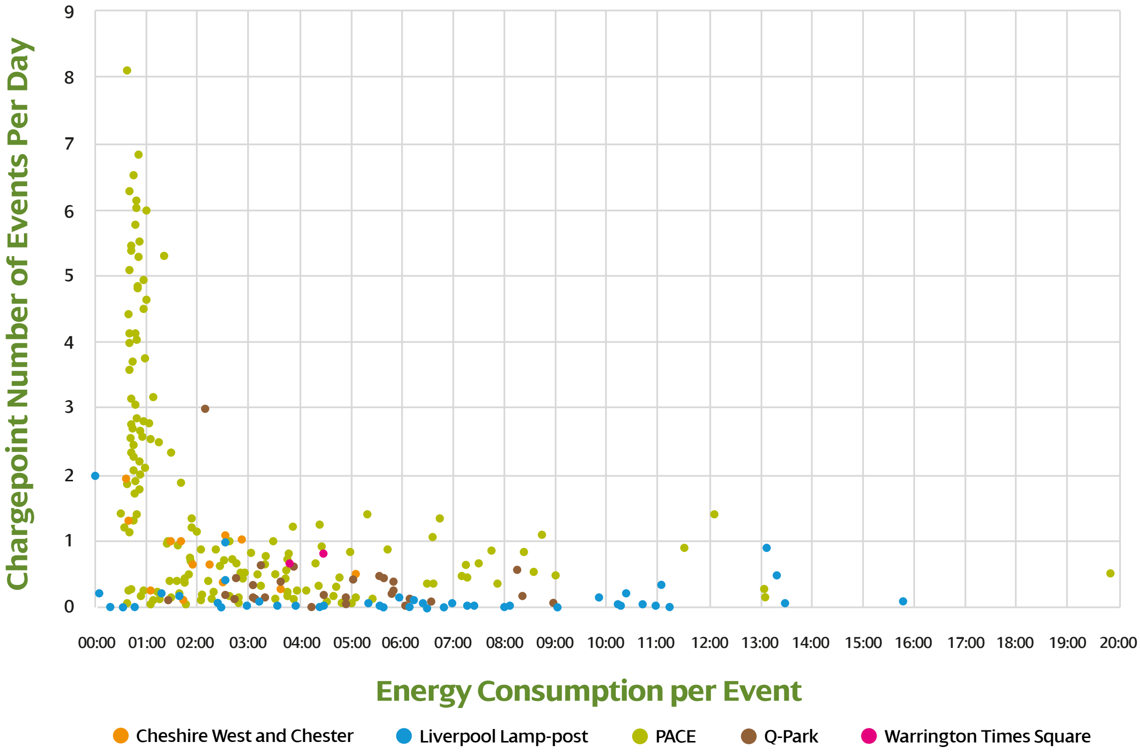

Figure 7: Mapping the Average Event Duration and Number of Events per Day to Each Chargepoint

Source Data	Average Chargepoint Utilisation
Cheshire West and Chester	6.4%
Liverpool Lamp-post	3.6%
PACE	11.2%
Q-Park	6.0%
Warrington Times Square	12.7%
Total	8.9%

Table 2: Per-Chargepoint Average Utilisation

4. APPROXIMATION OF SCC VALUE – DESKTOP ASSESSMENTS

The Charge Project is delivering both Virtual Trials and desktop studies of SCC solutions for EV charging. Both require modelling of chargepoint utilisation and power demand across scenarios of varying chargepoint type, scale of EV charging, and EV type. The Virtual Trials and desktop studies were introduced to the Charge Project scope following challenges in the implementation of on-network Physical Trials of SCC solutions.

- The Virtual Trials will deliver a demonstration of SCC operation using physical distributed energy resources management system (DERMS) infrastructure alongside simulated network and EV chargepoint behaviours.
- The desktop studies will deliver simulation of SCC implementation to a larger range of network cases and study scenarios.

These trials will elicit learning from the specification, build and configuration of SCC-enabling infrastructure and improve understanding of the capacity release from SCCs, including typical levels of demand curtailment under different solution types and application cases.

This document details the results of the desktop studies, outlining the study objectives, study scenarios, and findings from the desktop simulation of SCC operation. The desktop studies demonstrate delivery of the DNO SCC solutions across a variety of use cases, both validating the DNO control technology and providing a practical illustration of chargepoint demand curtailment across different scenarios.

The high-level design for the desktop studies is detailed in document 200713-27B Desktop Studies High Level Design. This supporting document provides greater detail of the network scenarios under study, as well as the simulation methodology, environment, and modelling assumptions.

4.1. Desktop Assessment: Objectives

The desktop studies are delivered under the re-scoping of the Charge Project, following challenges in establishing suitable conditions for the project Physical Trials. Delivering desktop studies allows the investigation of SCC benefits across a much larger range of network cases and study scenarios. The study objectives are summarised below.

- Establish study environment for simulation of SCC deployment.
- Specify requirements for study of SCC deployment to estimate frequency of constraint and resultant curtailment actions.
- Establish and demonstrate a recommended methodology and best practice for delivery of the SCC curtailment study that can be rolled out by other DNOs.
- Study curtailment of SCCs in different deployment scenarios.
- Establish varied network cases and EV/SCC scenarios that reflect the diversity of potential deployment cases.

- For each case, study SCC operation and approximate curtailment of EV chargepoint events.
- Explore levels of capacity released between different SCC solutions.
- Establish standardised approximate curtailment ranges for different SCC deployment scenarios.
- From study scenarios, identify standardised combinations of SCC deployment and network cases.
- Approximate ranges of curtailment to be expected at EV chargepoints when SCCs are deployed to standardised network cases.

4.2. Input Datasets, Outputs and Study Scenarios

The desktop studies will, for each specified scenario, approximate the emergence of network constraints and the resultant active management of chargepoint sites under SCCs across a study year. The objective of desktop studies is to evaluate the volume of curtailment experienced by the chargepoint sites under study.

The desktop studies are based on constraint modelling methods that can be found applied to other forms of active network management (ANM). For example, modelling of curtailment for generators participating in ANM-facilitated flexible connection schemes follows a similar analytical process. The methodology uses time-series study of network conditions to identify periods when network constraint will emerge, and where necessary, simulates the network control actions that maintain the network within secure limits. In the context of SCCs, the network control action is the restriction of EV chargepoint import.

The following sections summarise:

- The format of input datasets applied to desktop assessments
- The outputs presented in each desktop study, providing approximations of EV chargepoint constraint
- The variables that are explored across the study scenarios, allowing comparison of EV chargepoint constraint across scenarios of varying characteristics

The study methodology and simulation architecture are presented in more detail in the document 200713-27B Desktop Studies High Level Design.

4.2.1. Input Datasets

The SCC desktop assessment studies require the datasets summarised in Table 3.

	Description
Measurement Point Loading Profiles	Half-hourly profile of power flow at network constraint locations that must be managed via the SCC solution. This is measured in MW.
Pre-Constraint EV Site Demand Profiles	Half-hourly profile of aggregated EV chargepoint demand for each EV site under study. This is measured in MW.
Sensitivity Factors	Factors representing the associative relationship between energy consumption at the EV chargepoint sites and power flow at the measurement points.

Table 3: Desktop Assessments – Input Datasets Summary

4.2.2. Output Datasets

The key outputs from the desktop assessment studies are the approximations of EV chargepoint curtailment across the full study year. This is of value when compared to their pre-constraint equivalent utilisation. The key output metrics presented for each EV site under study are described in Table 4.

Output Metric	Description
Percentage Energy Unmet	The proportion of desired demand at the EV site that is not met due to curtailment, presented as a percentage.
Pre-Constraint Utilisation	EV site utilisation[1], in pre-constraint conditions, that is the ratio of usage of all chargepoints at the site with respect to the full potential charging window, presented as a percentage.
Post-Constraint Utilisation	The EV site utilisation, as described for the previous metric, in post-constraint conditions, presented as a percentage.

Table 4: Desktop Assessments – Key Outputs

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1. Utilisation example: Where a chargepoint has an EV connected and charging across six hours in a day, it will have a utilisation of 25% (six hours of charging divided by 24 possible hours). Where one chargepoint has an EV connected and charging for six hours in a day, and a second chargepoint experiences 18 hours of charging, there is a combined utilisation of 50% (6+18 hours of charging divided by 48 possible hours of charging).

4.2.3. Study Scenario Variables

The desktop studies explore a wider range of network cases and scenarios than the Virtual Trials. The less-onerous computational requirements for desktop studies mean full-year study simulations can be rapidly delivered across sites.

The desktop studies will demonstrate SCC application to a variety of study scenarios, each one year in duration. The study scenarios are defined by the variables specified in each case.

Variable Under Study	Description
Location	Locations reflect different network cases, types of constraint (varying voltage level and single/multiple constraint cases), and EV chargepoint type.
Study Year	Years 2025 and 2030 are studied to demonstrate variation in network demand profile and the EV chargepoint demand profile (with greater chargepoint utilisation in 2030).
Deployed SCC Solution	Study of both DNO-led and customer-led SCCs allows comparison of relative capacity release across solutions.

Table 5: Desktop Assessment – Scenario Variables

4.3. Study Findings and Recommendations

This section details the summarised study conclusions on both a per-site and per-chargepoint type.

4.3.1. Summary of Results by Site

The following sections present the summary results from each network study case and study scenario.

The tables present the following parameters:

- Site Utilisation: the ratio of usage of all chargepoints at a site with respect to the full potential charging window, presented as a percentage. This is presented in both pre-constraint and post-constraint formats
- Unmet Energy: the proportion of desired demand at the EV site that is not met due to curtailment

Results are presented across scenarios for 2025 and 2030, in which the following solutions are modelled:

- Locally Managed Constraint (LMC) schemes, in which a single constraint and single EV chargepoint site are managed
- Customer Load Management (CLM), in which the customer demand is managed behind the meter against the firm headroom capacity
- Centrally Managed Constraint (CMC) schemes, in which multiple network constraints and EV chargepoint sites are managed

4.3.1.1. Sandbach Public Destination

For all chargepoint locations at Sandbach, the utilisation levels, pre- and post-curtailment, are shown in Table 6. Note that the pre-constraint utilisation is consistent for all three sites. The unmet energy due to constraint is presented in Table 7.

Site	Utilisation	Scenarios							
		Distribution Substation Constraint				Primary Substation Constraint			
		LMC 2025	LMC 2030	CLM 2025	CLM 2030	CMC 2025	CMC 2030	CLM 2025	CLM 2030
Westfields	Pre-Constraint	10.9%	21.3%	10.9%	21.3%	10.9%	21.3%	10.9%	21.3%
Westfields	Post-Constraint	10.7%	19.1%	10.2%	13.9%	10.4%	12.3%	0.0%	0.0%
CBC Office	Post-Constraint	10.7%	20.9%	10.7%	20.2%	10.3%	12.3%	0.0%	0.0%
Scotch Common	Post-Constraint	8.0%	6.7%	0.0%	0.0%	10.4%	12.3%	0.0%	0.0%

Table 6: Sandbach Destination Summary Results: Site Utilisation

Site	Scenarios							
	Distribution Substation Constraint				Primary Substation Constraint			
	LMC 2025	LMC 2030	CLM 2025	CLM 2030	CMC 2025	CMC 2030	CLM 2025	CLM 2030
Westfields	1.0%	10.0%	5.6%	34.9%	4.3%	42.5%	100%	100%
CBC Office	0.1%	1.7%	0.3%	5.3%	4.3%	42.3%	100%	100%
Scotch Common	26.1%	68.5%	100%	100%	4.4%	42.2%	100%	100%

Table 7: Sandbach Destination Summary Results: Unmet Energy

4.3.1.2. Warrington Public Destination

For the chargepoint location at Warrington, the utilisation levels, pre- and post-curtailment, are shown in Table 8. The unmet energy due to constraint is presented in Table 9.

Site	Utilisation	Scenarios			
		LMC 2025	LMC 2030	CLM 2025	CLM 2030
Times Square	Pre-Constraint	10.6%	21.3%	10.6%	21.3%
	Post-Constraint	10.5%	21.0%	10.5%	20.1%

Table 8: Warrington Destination Summary Results: Site Utilisation

Site	Scenarios			
	LMC 2025	LMC 2030	CLM 2025	CLM 2030
Times Square	0.1%	1.3%	0.6%	5.9%

Table 9: Warrington Destination Summary Results: Unmet Energy

4.3.1.3. Sandbach En Route

For the chargepoint location at Sandbach, the utilisation levels, pre- and post-curtailment, are shown in Table 10. The unmet energy due to constraint is presented in Table 11.

Site	Utilisation	Scenarios			
		CMC 2025	CMC 2030	CLM 2025	CLM 2030
Sandbach En Route	Pre-Constraint	10.3%	36.4%	24.0%	36.4%
	Post-Constraint	8.6%	27.0%	0.0%	0.0%

Table 10: Sandbach En Route Summary Results: Site Utilisation

Site	Scenarios			
	CMC 2025	CMC 2030	CLM 2025	CLM 2030
Sandbach En Route	15.9%	25.9%	100.0%	100.0%

Table 11: Sandbach En Route Summary Results: Unmet Energy

4.3.1.4. Hoole On-Street Residential

For all chargepoint locations at Hoole, the utilisation levels, pre- and post-curtailment, are shown in Table 12. The unmet energy due to constraint is presented in Table 13.

Site	Utilisation	Scenarios					
		LMC 2025	LMC 2030	CLM 2025	CLM 2030	CMC 2025	CMC 2030
Feeder 1	Pre-Constraint	13.0%	29.0%	13.0%	29.0%	13.0%	29.0%
	Post-Constraint	12.9%	28.6%	12.4%	0.0%	12.1%	17.7%
Feeder 2	Pre-Constraint	13.0%	28.8%	13.0%	28.8%	13.0%	28.8%
	Post-Constraint	13.0%	28.6%	12.5%	0.0%	12.2%	17.6%
Feeder 3	Pre-Constraint	12.8%	29.0%	12.8%	29.0%	12.8%	29.0%
	Post-Constraint	12.8%	29.0%	12.7%	0.0%	12.0%	17.8%
Feeder 4	Pre-Constraint	13.2%	29.1%	13.2%	29.1%	13.2%	29.1%
	Post-Constraint	13.1%	26.3%	9.6%	0.0%	12.2%	17.8%
Feeder 5	Pre-Constraint	13.0%	29.0%	13.0%	29.0%	13.0%	29.0%
	Post-Constraint	13.0%	29.0%	13.0%	29.0%	13.0%	29.0%

Table 12: Hoole On-Street Residential Summary Results: Site Utilisation

Site	Scenarios					
	LMC 2025	LMC 2030	CLM 2025	CLM 2030	CMC 2025	CMC 2030
Feeder 1	0.0%	0.6%	3.7%	100.0%	6.7%	38.5%
Feeder 2	0.0%	0.6%	4.0%	100.0%	6.5%	38.8%
Feeder 3	0.0%	0.1%	0.4%	100.0%	6.3%	38.6%
Feeder 4	0.2%	9.6%	26.8%	100.0%	7.6%	39.0%
Feeder 5	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 13: Hoole On-Street Residential Summary Results: Unmet Energy

4.3.1.5. Edge Lane En Route

For the chargepoint location at Edge Lane, the utilisation levels, pre- and post-curtailment, are shown in Table 14. The unmet energy due to constraint is presented in Table 15.

Site	Utilisation	Scenarios			
		LMC 2025	LMC 2030	CLM 2025	CLM 2030
Edge Lane En Route	Pre-Constraint	10.3%	37.6%	10.3%	37.5%
	Post-Constraint	10.3%	27.4%	10.3%	31.9%

Table 14: Edge Lane En Route Summary Results: Site Utilisation

Site	Scenarios			
	LMC 2025	LMC 2030	CLM 2025	CLM 2030
Edge Lane En Route	0%	15.1%	0%	27.0%

Table 15: Edge Lane En Route Summary Results: Unmet Energy

4.3.1.6. Deeside Industrial Estate Workplace Destination

For the chargepoint location at Iceland, the utilisation levels, pre- and post-curtailment, are shown in Table 16. The unmet energy due to constraint is presented in Table 17.

Site	Utilisation	Scenarios	
		CLM 2025	CLM 2030
Deeside Industrial Estate	Pre-Constraint	13.8%	9.6%
	Post-Constraint	12.4%	9.0%

Table 16: Iceland Destination Summary Results: Site Utilisation

Site	Scenarios	
	CLM 2025	CLM 2030
Deeside Industrial Estate	9.8%	6.0%

Table 17: Iceland Destination Summary Results: Unmet Energy

4.3.1.7. Old Swan On-Street Residential

For all chargepoint locations at Old Swan, the utilisation levels, pre- and post-curtailment, are shown in Table 18. The unmet energy due to constraint is presented in Table 19.

Site	Utilisation	Scenarios					
		LMC 2025	LMC 2030	CLM 2025	CLM 2030	CMC 2025	CMC 2030
Feeder 1	Pre-Constraint	12.9%	28.8%	12.9%	28.8%	12.9%	28.8%
	Post-Constraint	12.9%	28.8%	12.9%	28.8%	12.8%	24.9%
Feeder 2	Pre-Constraint	13.0%	28.8%	13.0%	28.8%	13.0%	28.8%
	Post-Constraint	13.0%	28.8%	13.0%	28.8%	12.9%	25.0%
Feeder 3	Pre-Constraint	12.8%	29.0%	12.8%	29.0%	12.8%	29.0%
	Post-Constraint	12.8%	29.0%	12.8%	29.0%	12.8%	28.6%
Feeder 4	Pre-Constraint					13.2%	29.1%
	Post-Constraint					13.2%	28.7%

Table 18: Old Swan On-Street Residential Summary Results: Site Utilisation

Site	Scenarios					
	LMC 2025	LMC 2030	CLM 2025	CLM 2030	CMC 2025	CMC 2030
Feeder 1	0.0%	0.0%	0.0%	0.0%	0.8%	13.5%
Feeder 2	0.0%	0.0%	0.0%	0.0%	1.1%	13.2%
Feeder 3	0.0%	0.0%	0.0%	0.0%	0.0%	1.2%
Feeder 4					0.0%	1.2%

Table 19: Old Swan On-Street Residential Summary Results: Unmet Energy

4.3.1.8. Blaenau Ffestiniog Public Destination

For the chargepoint location at Blaenau Ffestiniog, the utilisation levels, pre- and post-curtailment, are shown in Table 20. The unmet energy due to constraint is presented in Table 21.

Site	Utilisation	Scenarios	
		LMC 2025	CLM 2025
Blaenau Ffestiniog	Pre-Constraint	10.6%	10.6%
	Post-Constraint	9.9%	8.4%

Table 20: Blaenau Ffestiniog Destination Summary Results: Site Utilisation

Site	Scenarios	
	LMC 2025	CLM 2025
Blaenau Ffestiniog	6.2%	20.6%

Table 21: Blaenau Ffestiniog Destination Summary Results: Unmet Energy

4.3.2. Summary of Results by Type

This section details the summary approximations of constraint-level range across the various SCCs, different EV charging types, scales of chargepoint charging installation, and chargepoint utilisation levels. The approximations are high-level estimations of constraint level derived from study findings, and are used to inform inputs to the ConnectMore tool. The range parameters are defined in Table 22, and the value ranges are detailed for each form of EV charging across Table 23 to Table 26.

Parameter	Definition
Utilisation Range	The expected range of utilisation of a site with respect to the year of installation, location, PTV forecasted demand, and EV developer expectation of demand.
MW Headroom Ratio Range	The ratio of desired installed capacity to network headroom available with respect to the constraint locations.
Energy Unmet Range	The expected percentage of energy which will not be supplied to EV chargepoints when requested due to network constraints, predicted utilisation and requested capacity installed.

Table 22: Summary Results Table Key Metrics

4.3.2.1. Destination Charging

A summary approximation of the constraint-level range for Destination charging is presented in Table 23. Note that in the Primary Substation cases studied, there was insufficient headroom available for a CLM solution (hence the range of 1–100% constraint over the estimations); however, implementation of the CMC solution in this case allows capacity to be exploited and may facilitate EV chargepoint connection.

Where LMC cases are compared to the behind-the-meter CLM equivalent, studies have found that greater capacity can be released to EV chargepoints.

Site Type	Constraint	Solution	Utilisation Range	MW Headroom Ratio Range	Energy Unmet Range
Destination	Primary Substation	CLM	5–15%	1–2	0–100%
			5–15%	2–3	0–100%
			5–15%	3+	0–100%
			15–30%	1–2	0–100%
			15–30%	2–3	0–100%
			15–30%	3+	0–100%
			30%+	1–2	0–100%
			30%+	2–3	0–100%
			30%+	3+	0–100%
Destination	Primary Substation	CMC	5–15%	1–2	0–5%
			5–15%	2–3	5–20%
			5–15%	3+	20–100%
			15–30%	1–2	0–10%
			15–30%	2–3	10–50%
			15–30%	3+	50–100%

Site Type	Constraint	Solution	Utilisation Range	MW Headroom Ratio Range	Energy Unmet Range
			30%+	1–2	0–20%
			30%+	2–3	20–70%
			30%+	3+	70–100%
Destination	Secondary Substation	CLM	5–15%	1–2	0–5%
			5–15%	2–3	5–20%
			5–15%	3+	20–100%
			15–30%	1–2	0–10%
			15–30%	2–3	10–30%
			15–30%	3+	30–100%
			30%+	1–2	0–20%
			30%+	2–3	20–50%
			30%+	3+	50–100%
Destination	Secondary Substation	LMC	5–15%	1–2	0–1%
			5–15%	2–3	1–10%
			5–15%	3+	10–100%
			15–30%	1–2	0–5%
			15–30%	2–3	5–10%
			15–30%	3+	10–100%
			30%+	1–2	0–10%
			30%+	2–3	10–30%
			30%+	3+	30–100%
Destination	11kV Circuit	CLM	5–30%	1–3	0–10%
			5–30%	3+	10–100%
			30%+	1–3	0–20%
Destination	11kV Circuit	LMC	30%+	3+	20–100%
			5–30%	1–3	0–1%
			5–30%	3+	1–100%

Table 23: Summary of Destination Site Constraints

4.3.2.2. En Route Charging

A summary approximation of the constraint-level range for En Route Charging is presented in Table 24, and is derived from study of the Sandbach and Edge Lane En Route sites. Study of the En Route sites identified that CLM solutions presented limited capacity and higher levels of interruption than the DNO-Led SCCs that delivered management of EV chargepoints against real-time network capacity.

Site Type	Constraint	Solution	Utilisation Range	MW Headroom Ratio Range	Energy Unmet Range
En Route	Primary Substation	CLM	5–10%	1–3	0–50%
			10–30%	3+	0–100%
			30%+	1–3	0–100%
			30%+	3+	0–100%
En Route	Primary Substation	CLM	5–10%	1–3	0–20%
			10–30%	3+	20–100%
			30%+	1–3	0–50%
			30%+	3+	50–100%
En Route	11kV Circuit	CMC	5–10%	1–3	0–50%
			10–30%	3+	0–100%
			30%+	1–3	0–100%
			30%+	3+	0–100%
En Route	11kV Circuit	LMC	5–10%	1–3	0–10%
			10–30%	3+	10–100%
			30%+	1–3	0–20%
			30%+	3+	20–100%

Table 24: Summary of En Route Site Constraints

4.3.2.3. Residential Charging

A summary approximation of the constraint-level range for Residential On-Street Charging is presented in Table 25, and is derived from study of the Hoole and Old Swan residential areas. The CLM case studied is equivalent (e.g., has the same constraints) to the LMC case, in which, again, LMC releases greater capacity to connecting EV chargepoints.

Site Type	Constraint	Solution	Utilisation Range	MW Headroom Ratio Range	Energy Unmet Range
Residential	Secondary Substation	CLM	5–15%	1–2	0–5%
			5–15%	2–3	5–20%
			5–15%	3+	20–100%
			15–30%	1–2	0–10%
			15–30%	2–3	10–30%
			15–30%	3+	30–100%
			30%+	1–2	0–20%
			30%+	2–3	20–50%
			30%+	3+	50–100%
Residential	Secondary Substation	LMC	5–15%	1–2	0–1%
			5–15%	2–3	1–10%
			5–15%	3+	10–100%
			15–30%	1–2	0–5%
			15–30%	2–3	5–10%
			15–30%	3+	10–100%
			30%+	1–2	0–10%
			30%+	2–3	10–30%
			30%+	3+	30–100%
Residential	Secondary Substation (Multi-Constraint)	CMC	5–15%	1–2	0–5%
			5–15%	2–3	5–20%
			5–15%	3+	20–100%
			15–30%	1–2	0–10%
			15–30%	2–3	10–40%
			15–30%	3+	40–100%
			30%+	1–2	0–40%
			30%+	2–3	40–60%
			30%+	3+	60–100%

Table 25: Summary of Residential Site Constraints

4.3.2.4. Workplace Charging

A summary approximation of the constraint-level range for Workplace Charging is presented in Table 26, and is solely derived from study of the Deeside Industrial Park workplace case study.

Site Type	Constraint	Solution	Utilisation Range	MW Headroom Ratio Range	Energy Unmet Range
En Route	Primary Substation	CLM	5–10%	1–3	0–10%
			10–30%	1–3	10–30%
			30%+	1–3	30–100%
			5–10%	3+	0–20%
			10–30%	3+	20–50%
			30%+	3+	50–100%

Table 26: Summary of Workplace Site Constraints

5. VIRTUAL TRIALS: INTERIM LEARNING

The Virtual Trials demonstrate delivery of the DNO SCC solutions across a variety of use cases, both validating the DNO control technology and providing a practical illustration of chargepoint demand curtailment across different scenarios.

The Virtual Trials were delivered under the re-scoping of the Charge Project following challenges in establishing suitable conditions for the project's Physical Trials. The Virtual Trials are demonstrated through implementation of a DERMS solution, with trial objectives summarised in Figure 8.

Outputs from the Virtual Trials will be disseminated in subsequent project reporting. The following section highlights the key learning derived from the process of designing and configuring the Virtual Trial demonstration environment. It explains the requirements for configuration of a DERMS to deliver different SCC solutions, as well as protocol and interface considerations for designing these solutions.

Establish Study Environment for Simulation of SCC Deployment

- Specify requirements for study of SCC deployment to estimate frequency of constraint and resultant curtailment actions.
- Establish and demonstrate a recommended methodology and best practice for delivery of the SCC curtailment study that can be rolled out by other DNOs.

Study Curtailment of Smart Charging Connections (SCCs) in Different Deployment Scenarios

- Establish varied network cases and EV/SCC scenarios that reflect the diversity of potential deployment cases.
- For each case, study SCC operation and approximate curtailment of EV chargepoint events.
- Explore levels of capacity released between different SCC solutions.

Establish Standardised Approximate Curtailment Ranges For Different SCC Deployment Scenarios

- From study scenarios, identify standardised combinations of SCC deployment and network cases.
- Approximate ranges of curtailment to be expected at EV chargepoints when SCCs are deployed to standardised network cases.

Figure 8: Virtual Trial Objectives

5.1. SCC Schemes Under Trial and Implementation Components

The SCC solutions have been previously defined in Charge Project documentation[2]. The following SCCs were considered for implementation in the Virtual Trials:

- TCC – Timed Capacity Connection: DNO-defined capacity but customer-led solution
- CLM – Customer Load Management: DNO-defined capacity but customer-led solution
- LMC – Locally Managed Connection: DNO-led solution
- CMC – Centrally Managed Connection: DNO-led solution

The hardware and user functionality of each SCC scheme is assessed in Table 27, in which the key DERMS architecture components are aligned with the SCCs.

Item	TCC	CLM	LMC	CMC	Description
Central DERMS Platform	N	N	N	Y	A centralised management platform providing centralised control and data-logging capabilities for simultaneous management of multiple EV sites. Control signals in the form of dynamic power demand set-points issued to EV sites provide a mechanism for maintaining overall site power load within safe limits. The platform is able to measure multiple constraint points on complex electrical network arrangements. The user interface provides a front-end display to control and monitor multiple EV site statuses and access historical data trending and event messaging.
Local DERMS Controller	N	Y	Y	Y	A local controller at an individual EV site provides local, self-managed control of the site. This can be configured as a stand-alone controller (applicable to CLM and LMC SCC schemes) or interfaced with a centralised DERMS management platform (applicable to a CMC SCC scheme). Control signals in the form of dynamic power demand setpoints issued to the EV sites provide a mechanism for maintaining overall site power load within safe limits. The controller is able to measure a single constraint point on a low-voltage electrical network. A local human-machine interface provides a graphical display to monitor EV site status and provide event messaging. There are no data logging or archive data display capabilities. It has no means of remote access, so users must be physically present at the local DERMS controller to interrogate display.

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[2] Document: SDRC 4A Refinement of Smart Charging Connections

Item	TCC	CLM	LMC	CMC	Description
Measurement Point	N	N	N	Y	An electrical network constraint point where the network flows must be managed to ensure operation within safe thresholds.
Circuit Breaker	N	Y	Y	Y	A site circuit breaker operated by a local DERMS controller provides a means of isolating the EV site from the electrical network as a failsafe response to fault conditions. It provides safety to the DNO electrical network. For CMC/LMC SCC schemes the DNO-owned infrastructure would operate the Circuit Breaker. For a CLM SCC scheme, the customer-owned infrastructure would operate the circuit breaker. The circuit breaker can be controlled by the central DERMS platform and local DERMS controller.
CPO Back-Office Interface					This is the interface between the DERMS network management (either central DERMS platform or local DERMS controller) and the EV site back-office management system. The specific means of interface protocol will differ on a site-by-site basis.

Table 27: SCC Scheme Overview

5.2. Integration of DNO and CPO Feedback

Engagement with DNO and CPO stakeholders shaped the Virtual Trial demonstration environment.

CPO engagement informed:

- The models of simulated CPO control behaviour when responding to SCC curtailment signals (Section 5.2.1)
- The specification of protocols for data exchange with CPO back-office systems (Section 5.2.2)

Combined DNO and CPO engagement informed:

- The specification of requirements for site circuit breaker control (Section 5.2.3)
- The requirements for physical installation of a local DERMS controller (Section 5.2.4)

5.2.1. Chargepoint Load Management

CPO control systems must deliver real-time load management at on-site chargepoints, for which several control strategies can be implemented. This is explored in the Virtual Trials; through application of different chargepoint load management strategies, the CPO Simulator replicates a wider number of real-life site chargepoint management behaviours.

Virtual Trial testing performs a comparison between each chargepoint load management method and studies the responsiveness and flexibility of each potential solution option.

5.2.1.1. Dynamic Load Balancing

Discussions with CPOs identified that in most cases, chargepoints were technically capable of being controlled to consume energy at a reduced percentage (%) of the chargepoint rated kW capacity. This allows implementation of Dynamic Load Balancing control, in which all chargepoints are treated equally and consumption is reduced by the same percentage level. (Not all chargepoint models may have this control capability.)

To investigate this Dynamic Load Balancing behaviour, the CPO Simulator developed by SGS for the Virtual Trials incorporates this control method as a selectable CPO site configuration option.

5.2.1.2. Round Robin Scheduling

In a discussion with a specific CPO that is developing an EV site utilising DC-based chargepoints driven from an ESS battery arrangement, it was identified that these chargepoints did not include functionality to consume a dynamically reduced load. In such a case, the chargepoint load management must be achieved by selectively switching off the necessary number of chargepoints in a periodic cycle utilising a Round Robin fixed time scheduling algorithm.

To investigate this Round Robin scheduling behaviour, the CPO Simulator developed by SGS for the Virtual Trials incorporates this control method as a selectable CPO site configuration option.

5.2.2. Back-Office DERMS Interface

Insights regarding the interface between DNO DERMS infrastructure and CPO back-office management systems were captured through engagement with CPOs. The interface between DERMS and CPO systems is responsible for site demand setpoints and the CPO sharing visibility of total site demand.

5.2.2.1. Protocols

Of the CPOs involved in discussions, none of their corresponding back-office management systems currently incorporated functionality for an external interface to a third-party DNO DERMS system. Software development work would be required on the back-office management side to implement such an interface, and management software functionality would subsequently need to be developed to provide chargepoint control actions to implement the setpoint and reduce power load accordingly.

These discussions identified that at present no preferred protocol communication standard was the clear industry leader. A review of potential protocols is presented in Section 5.3. If no existing standard met the criteria, a bespoke REST API interface tailored to EV site control was considered a suitable option.

The use of a REST API-based communication protocol was the preferred option. The REST API server would reside on the CPO back-office infrastructure, with a REST API client interface on DERMS initiating the connection to the server.

Common industrial transmission standard protocols such as DNP3 or Modbus are unlikely to be widely used for these cloud-based communications.

5.2.2.2. Back-Office Management System Infrastructure

Of the CPOs engaged, including the sites considered for Charge Project Physical Trials, most CPO back-office management systems were cloud-based.

There is unlikely to be physical back-office management infrastructure at an EV site level to allow a wired interface to a local DERMS controller; therefore, DERMS design must consider the range of local controls available for a given EV site and provide several options.

5.2.3. Site Circuit Breaker Control

Stakeholder discussions explored the requirement for control of the site circuit breaker, providing DERMS fail-safe escalated control actions in response to failure of the CPO back-office management system to deliver the required chargepoint control.

In general, CPO back-office management systems provide an interface to chargepoints only, and do not include any functionality for the back office to control electrical infrastructure, such as circuit breaker actions to isolate the CPO site from the DNO network. A local DERMS controller would therefore always be necessary at each CPO site to deliver circuit breaker control. Alternatively, an architecture with no local circuit breaker control (without any local DERMS controller installed) could be proposed if an alternative means of ensuring DNO network integrity was available for a given site.

CPO stakeholders were concerned that tripping a CPO EV site would potentially also isolate other non-EV infrastructure, such as shop facilities and lighting. This is not regarded as a desirable outcome of DERMS fail-safe control. One means of addressing this challenge is for the electrical layout of a proposed EV site to be designed to segregate the chargepoint electrical supply on a dedicated circuit breaker, separate from other, non-EV electrical infrastructure.

5.2.4. Physical Installation of Local DERMS Controller

During discussions with prospective CPO partners for the project Physical Trials, feedback included that the dimensions of the proposed local DERMS controller, to be installed for delivery of CLM and LMC SCC schemes, were too large to fit within the available mounting space at CPO sites.

In response to this stakeholder feedback, the dimensions of the local DERMS controller used within the Virtual Trials was reduced to a smaller footprint. However, these dimensions cannot be reduced any further whilst maintaining device functionality, and may still be too large for installation at certain EV sites.

The local DERMS controller may not be suitable for smaller connections for which there is no physical building available at the EV site to house the controller. This may limit EV site suitability for LMC and CLM SCC scheme-type architectures for which there is no centralised management CMC platform.

The learning from this feedback reinforces the need for a site survey to be undertaken prior to provision of an SCC scheme with a local DERMS controller.

A potential redesign of a reduced footprint panel for a back-office cloud interface device should also be investigated to assess the hardware requirements of such a device. This would provide a range of different local DERMS controller options for both simple and more complex site arrangements.

Alternatively, for a CMC SCC scheme, a central-only architecture without any local DERMS controller may be suitable for sites with insufficient local physical space.

5.3. Review of Protocols

This section provides a review of prospective protocols for implementation in the interface between the DERMS and CPO back-office management system.

5.3.1. Open Smart Charging Protocol (OSCP)

The Open Smart Charging Protocol (OSCP) v2.0 was released in Oct 2020 and defines a protocol for flexible energy resources based on available capacity.

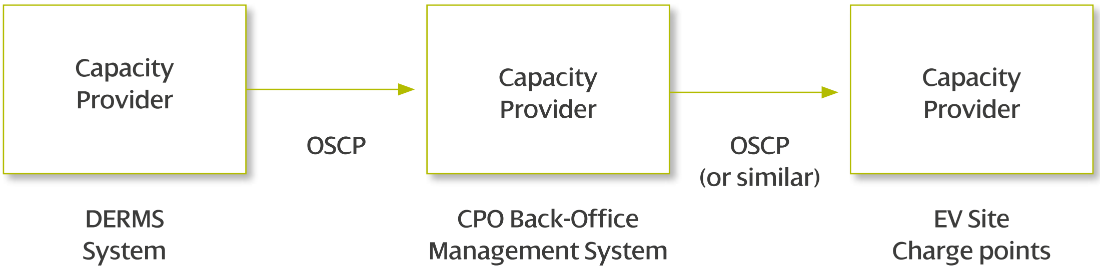

Figure 9: OSCP Block Diagram

The protocol uses a REST API client/server arrangement to exchange data.

The OSCP signal to the Flexibility Provider supplies forecast information in the form of a 'Capacity Forecast'

5.3.1.1. Capacity Forecast

The OSCP Capacity Forecast consists of several time intervals defining the forecasted consumption limits during the time intervals. The diverse types of forecasts are:

- **Consumption Capacity:** specifies the maximum total capacity bandwidth range for a given time interval – a positive value
- **Generation Capacity:** specifies the maximum total generation bandwidth range for a given time interval – a negative value. This is not applicable for the Charge Project EV context, as vehicle-to-grid (V2G) export generation is not considered
- **Fallback Consumption Capacity:** during periods of communication loss, the reduced Consumption Capacity
- **Fallback Generation Capacity:** during periods of communication loss, the reduced Generation Capacity – this is not applicable to the Charge Project EV context
- **Optimum:** a desired optimum amount to be consumed (or generated) – single value, rather than a range

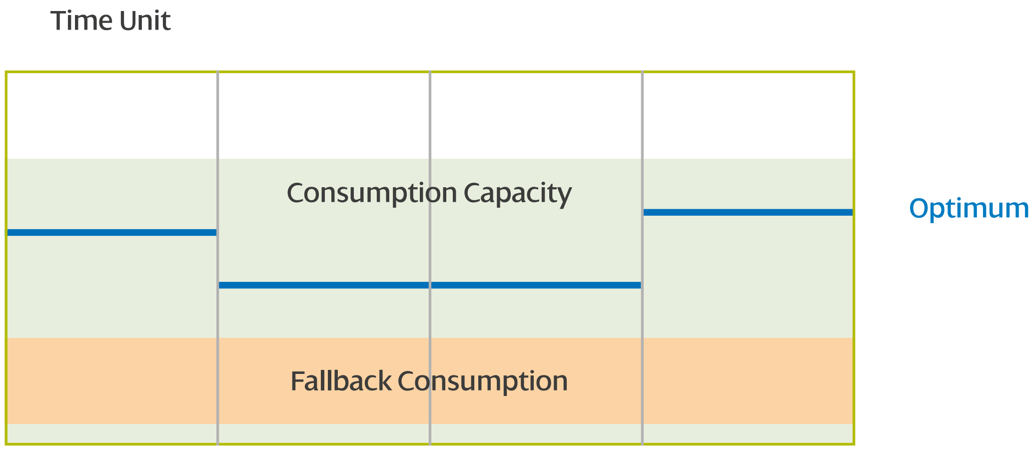

Figure 10: OSCP Capacity Forecast

5.3.1.2. Suitability of the OSCP for the Charge Project

The concept of the protocol does map to the DERMS concept, wherein the DERMS setpoint informs the 'Optimum' Capacity Forecast.

The protocol is intended for use with future flexibility markets. This dynamic future schedule aspect does not necessarily fit with the DERMS dynamic setpoint approach. For the Charge Project, the Optimum capacity would need to be continually updated in real time as a dynamic setpoint. This approach could be achieved with the protocol, but does not use the protocol as intended. Effectively, the forecast would always be concerned with the single next time interval and repeatedly adjusting the Optimum capacity for that next time interval (in response to dynamic changes to the DERMS setpoint).

The protocol is REST API based, so would be suitable for incorporation into a DERMS from a protocol integration perspective.

As this version of the protocol was released in 2020, the CPO back-office management system uptake has been slow. None of the CPO stakeholders engaged through the Charge Project presently support the protocol.

5.3.2. OpenADR

The OpenADR 2.0 profile specification is a flexible data model to facilitate common information exchange between electricity service providers, aggregators, and end users. The concept of an open specification is intended to allow anyone to implement the two-way signalling systems. Servers publish information to the automated clients, which subscribe to the information.

OpenADR can be used to exchange electricity pricing scheduling information and provide 'demand response' signals.

5.3.2.1. Message Exchange

Communication is between two devices. Server devices are identified as Virtual Top Node (VTN) and clients identified as Virtual End Node (VEN).

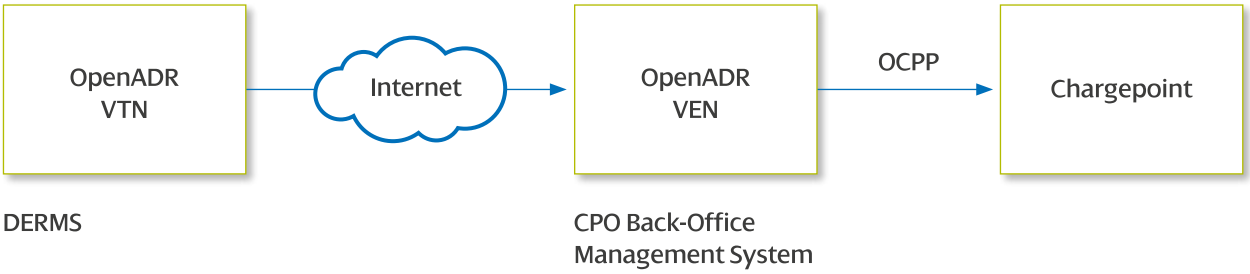

Figure 11: OpenADR Node

Figure 11 shows an example of how OpenADR would be applied in the context of the Charge Project for communications between a DERMS and CPO back-office management system.

5.3.2.2. Web Services

OpenADR provides the functionality described in Table 28.

Web Service	Description	Payloads
EiEvent	Send/acknowledge demand response events	oadrRequestEvent oadrDistributeEvent oadrCreatedEvent oadrResponse
EiOpt	Temporary availability schedules	oadrCreateOpt oadrCancelOpt
EiReport	Request and deliver reports	oadrRegisterReport oadrCreateReport oadrUpdateReport oadrCancelReport
EiRegisterParty	VEN registration	oadrCreatePartyRegistration oadrCancelPartyRegistration oadrRequestReRegistration

Table 28: OpenADR Web Services

Each web service can perform different payload operations.

5.3.2.3. Suitability of OpenADR for the Charge Project

CPO back-office management system uptake is not currently present. None of the CPO stakeholders engaged in the Charge Project presently support OpenADR.

5.3.3. Open Charge Point Interface (OCPI)

5.3.3.1. OCPI Introduction

Open Charge Point Interface (OCPI) is an open standard providing a mechanism for exchange of data, primarily intended for EV roaming support between CPOs and e-mobility service providers to offer roaming customer billing.

The OCPI standard includes support for exchange of smart charging information between CPOs and smart charging service providers (SCSPs), such as the DNO DERMS infrastructure in this context.

The current version of the OCPI standard is version 2.2.1.

This section describes the general message exchange interface mechanism of the OCPI standard (via a REST API message-exchange mechanism) and summarises the smart charging support. The suitability of the smart charging functionality from a Charge Project perspective is considered.

5.3.3.2. REST API Message Exchange – General Operation

RESTful web services are an HTTP-based protocol used to exchange information as JSON formatted data. RESTful web services expose specific API end-point addresses to allow client access to specific resources from the server.

RESTful web services provide the following methods for data exchange:

- GET: retrieve a resource
- PUT: create a new resource
- POST: update an existing resource
- PATCH: partial update of a resource
- DELETE: remove an existing resource

Clients use these methods to read and write data of exposed server resources. RESTful web services are 'stateless', so each message is fully self-contained, without the use of any session history. When a message is successfully received, a subsequent response message is returned. Message security at the HTTP transport level uses standard HTTPS SSL server certificates for encrypted communications.

5.3.3.3. Security

In addition to the HTTPS encrypted communications, the OCPI message standard requires every message to contain an authorisation header token ID string to uniquely confirm the source of the messages.

5.3.3.4. OCPI Modules

The OCPI standard is separated into several different 'Modules' providing various charging-related data exchanges for charging sessions (such as session billing, tariffs and chargepoint locations).

This document describes the relevant modules from an SCSP role perspective only.

5.3.3.5. Credentials

The Credentials Module is employed by all user roles to exchange security authorisation token IDs prior to exchange of OCPI messages.

From an SCSP perspective, the SCSP sends a message to the CPO to identify the CPO-supported OCPI versions and the appropriate end-point URLs. Further messages will then be exchanged to set up the security authorisation token IDs to be used for the OCPI messages between the two parties.

5.3.3.6 Smart Charging

The Smart Charging Module allows parties to send Smart Charging Profiles to a specific EV charger session. The EV charger may receive profiles from multiple sources (depending on the configuration arrangement) and decide what charging action to take. The *ActiveChargingProfile* data identifies the profile in use by the chargepoint performing the EV charging session.

The *ChargingProfiles* identify a maximum charging limit rather than an exact target setpoint. Other external factors (such as absence of three-phase power support of the EVSE charging cables) may affect the chargepoint charging rate in practice.

5.3.3.6.1. ChargingProfile

A *ChargingProfile* contains the following properties:

Property	Description
Start Time	Absolute starting point of profile or relative to start of charging session
Profile Duration	Can be finite duration or set indefinitely
Charging Rate Unit	Power (watts) or current (A)
Min Charging Rate	Minimum charging rate supported by EV
ChargingProfilePeriod **[Can consist of an array of multiple *ChargingProfilePeriods.* See Table 30]**	Maximum charging power (or current) during the charging period This charging period can be offset from the beginning of *ChargingProfile* start time This property can contain multiple ***ChargingProfilePeriod*** entries to modify the maximum rate throughout the profile

Table 29: OCPI ChargingProfile Properties

Property	Description
Start Period	Start of period, from start of profile
Limit	Maximum charge rate limit during profile period, expressed in ***ChargingProfile*** 'Charging Rate Unit'

Table 30: OCPI ChargingProfilePeriod Properties

The intention of these profiles is to manage the load of a specific EV charge session, such as to begin a session at a higher charging level and then reduce this limit after a period. Different *ChargingProfiles* can be invoked during a charging session.

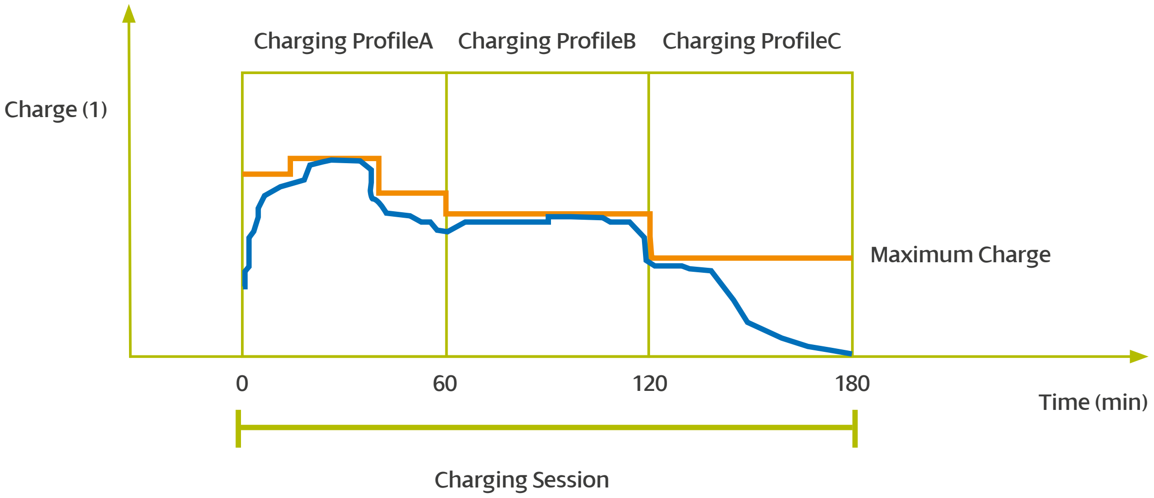

Figure 12: OCPI Charging Profiles

Figure 12 shows a hypothetical example set of charging profiles for a single EV charging session. The red line shows the charging profile limit, and the blue line shows the EV power load responding to changes in limit.

5.3.3.7. Limitations of OCPI Smart Charging

The Smart Charging defined in the standard is solely focused on individual charging sessions for connected EVs, as well as the control of that session throughout the charging period. If a site has multiple EVs connected at any given time, multiple charging sessions will need to be managed separately.

The OPCI smart charging is aimed at the low-level CPO management of the connected EVs (or the SCSP low-level management of connected EVs on behalf of the CPO). There is no definition within the OCPI v2.2 standard for read or control of the charging level from an overall site perspective.

5.3.3.8. Suitability of OCPI for the Charge Project

OCPI standard does not provide support for the smart charging-related single overall aggregated setpoint that the Charge Project is aiming to provide. It also does not include any support for directly reading the instantaneous chargepoint charging rate collectively at a site level.

Manipulating the OCPI charging profiles requires management of each individual EV charging session. This management of chargepoints is within the role of the CPO back-office management system. Implementing an OCPI interface in DSO DERMS infrastructure would require research and development of both an OCPI RESTful server API (to receive OCPI messages initiated from CPO) and an OCPI client (to send OCPI messages to the CPO).

An alternative approach might be to use the OCPI as a means of information transfer and build bespoke functionality on top of the existing standard. This could include overall site power usage and a desired setpoint. This approach would require collaboration with the CPO back-office management software developers to introduce this additional functionality.

5.3.4. SGS Defined Interface

An alternative approach is to define a bespoke interface. This interface can be tailored to meet the specific smart charging requirements of the Charge Project.

Following stakeholder feedback, a REST API-based protocol interface was identified as a suitable option. The general principles of message exchange are described in Section 5.3.3.2.

The bespoke aspect is the end points that are exposed in the REST API server:

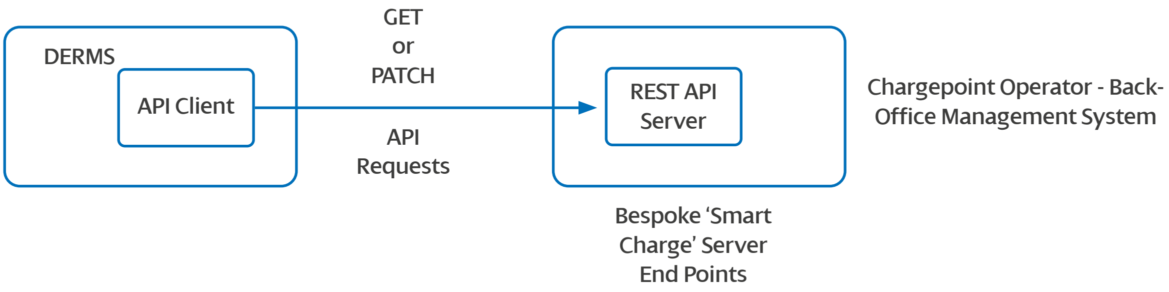

Figure 13: Bespoke REST API Interface

This is the preferred approach to be implemented in the Virtual Trials.

The REST API server is installed on the CPO back-office management system, with a DERMS REST client interfacing with the server. The CPO back-office owners are responsible for implementing the REST API server, based on a supplied specification.

The output of the Charge Project would be the definition of the REST API server interface.

5.3.4.1. Suitability of Bespoke REST API Interface for the Charge Project

Defining a bespoke 'smart charge' end-point interface provides flexibility, as the signals can be exchanged to meet the needs of the Charge Project. This is thought to be a better solution than trying to make partial use of an existing protocol, such as OCPI, to fit the project's needs.

The definition of a REST API server will be developed as part of the Virtual Trials.